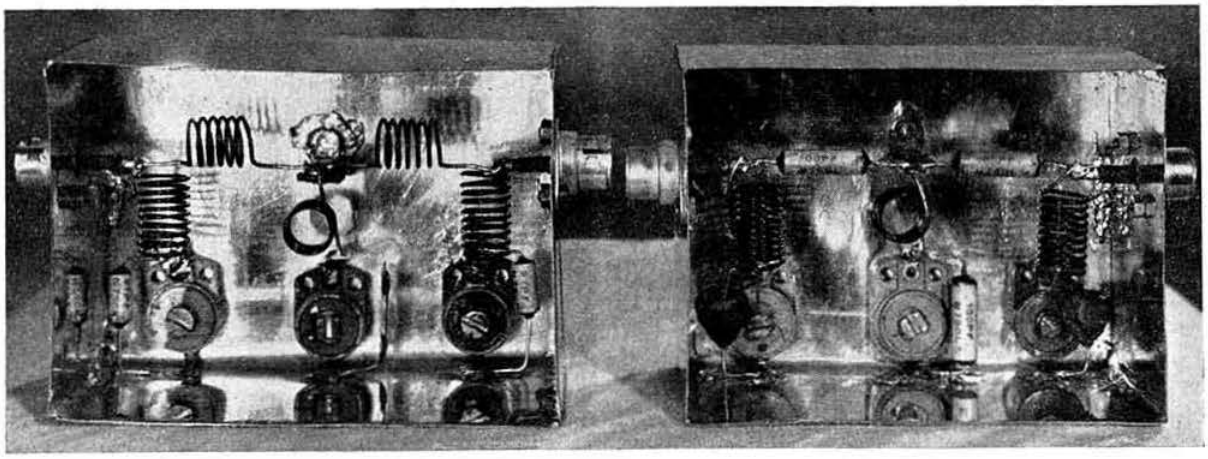

Low and High Pass Filters for All

Simplified Designs for Home Construction

By DAVID DEACON (G3BCM)*

LOW and high pass filters may be readily made at home and once constructed are most useful in connection with measurements on transmitters and television receivers even if not actually required in cases of interference. For some time past the TVI/BCI Committee has been studying the practical aspects of assembling and aligning simple but effective filters of these types and it is the purpose of this article to describe some examples providing high attenuation across the standard U.K. television receiver intermediate frequency band 33·4 to 38·4 Mc/s. Work has been concentrated on this range because it is now in nation-wide use in all currently produced receivers irrespective of local channel frequencies.

It is apparent that even in areas of comparatively high level television signals interference does occur, due in almost every case to i.f. break-through or swamp although no properly designed superhet receiver should suffer from this type of trouble. The problem can generally be overcome by inserting a bandpass filter or an i.f. transformer in series with the grid lead to the mixer valve preceding the i.f. chain concerned. If the rejector device is simply placed in the aerial lead, it must not be overlooked that through stray capacity coupling and ineffective screening an interfering signal may still reach the mixer stage through the r.f. stage(s) and pre-mixer circuitry.

The protection of national broadcasting and television i.f. bands places a heavy responsibility on all concerned in the field of radio engineering and not least of all on the radio amateur. However, it is not the intention to indulge in polemics regarding the proper design of television and broadcast receivers in this instance.

In a properly constructed amateur transmitter the harmonic component should be at least 40db down on the fundamental. (This figure relates to the effective radiated power at the transmitter output terminals.) On no account should the power of the harmonics radiated from the chassis or connecting leads exceed that measured at the aerial terminals. Sub-harmonics from early stages of the transmitter are included in this test.

Filters to be described in this article should provide some 40db or more of attenuation so a practical total for the attenuation of harmonics in a well-designed installation should be of the order of 80db. In round figures and assuming a transmitter operating at 150 watts input and 66 per cent efficiency, the e.r.p. of which is 100 watts, 40db design attenuation reduces harmonic radiation to 10 milliwatts; a 40db filter further reduces this figure to 1 microwatt, a not impossible achievement with present-day h.f. transmitters for amateur use.

Filter Design

To encourage the widest construction and adoption of these filters particularly in transmitter outputs, a standard but relatively simple circuit has been adopted. Only very elementary hand tools are required to build them and, except for the tin box, most of the materials should be on hand or readily and cheaply obtainable. No special skill is required and, provided reasonable care and attention is paid to the winding details for the inductors and to the location of the components, the results attained should be equal to if not better than those achieved with the prototype filters made by the Committee.

The photograph at the top of the page shows examples of the low pass (left) and high pass (right) types.

The filters employ "m" derived end sections in conjunction with "m" derived "T" centre sections. Individual component values have been determined to allow the mean band of high attenuation between 32 and 38 Mc/s to be adjusted by approximately ± 10 per cent.

The input and output characteristic impedance is centred on 75 ohms. This facilitates the use of co-axial cable and

* *Chairman, TVI/BCI Committee, 17 Lonsdale Road, South Norwood, London, S.E.25.*

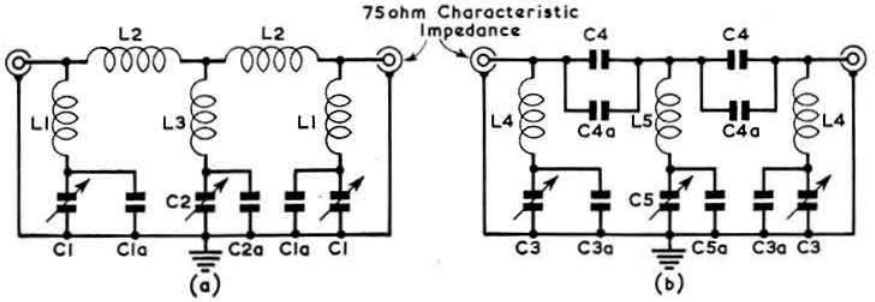

Fig. 1. (a) Low pass filter. (b) High pass filter. The fixed capacitors marked " a " indicate that the capacitor is in fact made up of fixed and variable capacitors as indicated in the Table.

connectors which, in conjunction with a good earth system, should ensure effective screening of the " filtered " lead-through and thereby optimum performance.

The low pass filter is for transmitter r.f. output circuits using co-axial 75 ohm cable. The high attenuation mean band is 32 Mc/s to 38 Mc/s adjustable ± 10 per cent. The cut-off frequency is 32 Mc/s ± 10 per cent. It employs five inductors, three capacitor combinations, two co-axial connectors and a tag strip mounted in a tinned-iron box.

The high pass filter is for television co-axial aerial feeder circuits of 75 ohm characteristic impedance. The high attenuation mean band is 32 to 38 Mc/s adjustable ± 10 per cent. The cut-off frequency is 38 Mc/s ± 10 per cent. It employs five capacitor combinations, three inductors, two co-axial connectors and a tag strip mounted in a tinned-iron box.

In order to simplify the construction as much as possible, neither filter has internal screening between its various branches. Even so, their effectiveness is quite impressive in a correctly matched system, and they should give a good account of themselves in operation.

Fig. 1 shows the circuits of both types. As long as there are no abnormal standing-waves or excessive transmitter harmonics on any part of the feeder system, the components specified for the low pass filter are adequate for h.f. transmitters with d.c. inputs up to 150 watts.

The theory, operation and characteristics of filters will not be dealt with here but may be studied in detail in textbooks and amateur handbooks. Several useful articles have been published in the R.S.G.B. BULLETIN. [1, 2, 3, 4].

Box Construction and General Details

In view of the need to obtain positive contact particularly in the screen and earthed side of the filter network as well as to ensure that in use there can be no possibility of contact rectification occurring, tin-plate (tinned iron) is far superior to aluminium for the box. Tin-plate of 20/22 gauge lends itself to bending and soldering as well as affording screening of the magnetic component of the r.f. current flowing in the filtered lead.

To allow adequate separation between the inductors in each branch of the filter and the minimum of interaction in the absence of internal screening, the box should be made at least 4 in. long, 3 in. wide and 2 in. deep. Suitable tinned-iron boxes may well be obtained from retail shops. Fig. 2 shows the general arrangements for making them up. Proportional adjustments in the marking out should be made for boxes with different dimensions to those shown for reference in Fig. 2.

After marking out and either drilling or punching all the holes in the flat pieces of metal, the box can be bent into shape. To facilitate this, a block of wood, preferably a hard variety cut to the internal dimensions of the box, will be found most useful. *If the box is constructed in this way it is advisable to cut the wood block to size first and then to mark out the tin-plate sheet allowing for the thickness of the metal.* To make the lid a good fit it should be formed in position on the box with the block of wood inside. In this way the lips of the lid may be hammered into their final close fitting form using another piece of hardwood between them and the hammer head. Self-tapping P.K. screws can be used to fix the lid to the box, or alternatively it may be fixed with a number of spot solder joints, but not until the unit has been checked and aligned.

The seams of the box should be soldered with a hot iron. Care in carrying out this operation should result in a smooth and mechanically sound joint which will make the box extremely rigid. Where material for the box is not

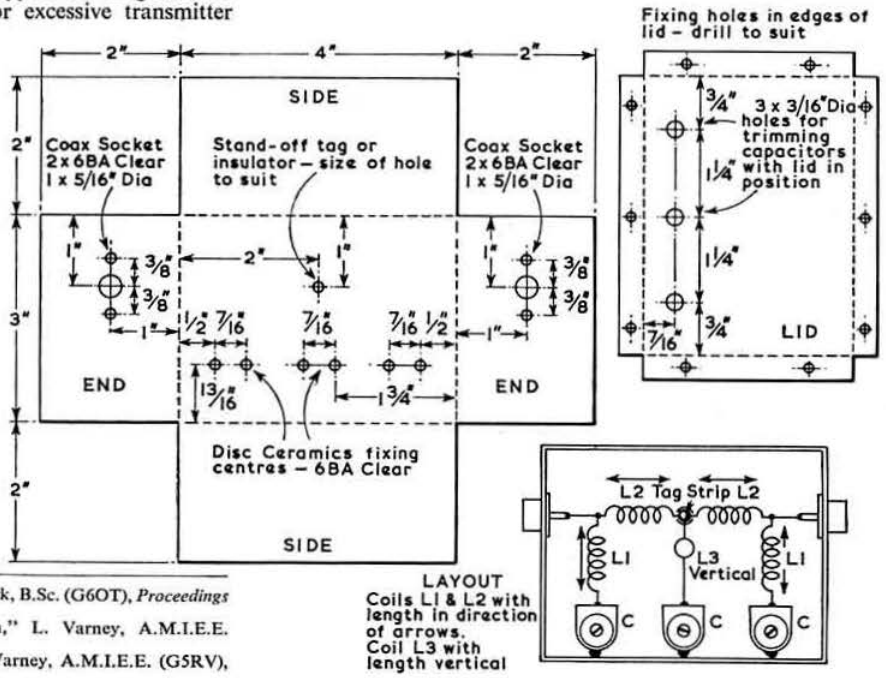

Fig. 2. Drilling details for the filter box. The layout of the low pass filter is shown in the small diagram at the lower right.

[1] " Impedance Matching," H. A. M. Clark, B.Sc. (G6OT), *Proceedings of the R.S.G.B.*, No. 6, Summer 1949.
[2] " Television Interference Suppression," L. Varney, A.M.I.E.E. (G5RV), March 1950.
[3] " An Improved Low Pass Filter," L. Varney, A.M.I.E.E. (G5RV), June 1952.
[4] " Low Pass Filters for Television Interference Reduction," L. Knight. Grad. I.E.E. (G2DXK), May 1953.

available in the correct size, it is practicable to solder together the individual sides, ends and bottom using the wood block as a jig. The 20/22 gauge tinned-iron sheet for the box is generally available from ironmongers in sheets measuring 20 in. by 28 in. for about 5s. This quantity is sufficient to make about five or six boxes to the pattern of Fig. 2.

Other materials required in constructing each filter are two co-axial sockets, 6 B.A. nuts and bolts, a small stand-off insulator or tag strip, self-tapping screws, insulated sleeving, tinned copper wire, a reel of 18 s.w.g. enamelled wire and strips of rubber, Perspex or wood for the underside of the box.

Assembling and Connecting Up

Before construction commences, the inductors, capacitors, co-axial sockets and the tag strip should all be tinned. When this has been done the following assembly procedure will be found a useful guide:

(i) Fix the ceramic variable capacitors in position as indicated in Fig. 2, using 6 B.A. nuts and bolts. (The heads of the bolts should be on the underside of the box.)
(ii) Fit the co-axial sockets and tag strip.
(iii) Add the fixed capacitors in parallel with the variables, at the same time securely soldering the earthy ends to the tin box using the shortest possible leads.
(iv) The three series inductors (L1, L3 or L4, L5) should then be connected between the free ends of the capacitors and the co-axial connectors or tag strip points. Note that the centre inductors should be fixed at right angles to the two end inductors.
(v) Finally, depending on whether the filter is low or high pass, the in-line inductors (L2) or capacitors (C4) may be soldered into position.

This completes the construction but in order to ensure that the screw heads on the underside of the box do not damage any surface on which the unit may be placed it is as well to affix small pieces of rubber, Perspex or wood strips to the bottom.

Checking and Adjusting

Before attempting to make any tuning adjustments on the filters it is as well to test for continuity, open-circuits or short circuits using Figs. 1 (a) and (b) for reference.

With a grid-dip oscillator which covers 30 Mc/s to 40 Mc/s (preferably calibrated at least at each Megacycle) adjustment of the filter may be carried out using the simple test circuit shown in Fig. 3.

The alignment procedure for each type of filter is as follows.

Low Pass Filter With the test oscillator set at 30 Mc/s adjust the link coupling to give about 300 microamps deflection on the meter with the filter out of circuit. Set the oscillator to 32 Mc/s and connect up the filter as shown in Fig. 3. Tune each C1 until the meter reading just begins to fall. By doing this a number of times and by swinging the oscillator from 30 Mc/s to 40 Mc/s in the process the function of the filter will become apparent. When this has been done,

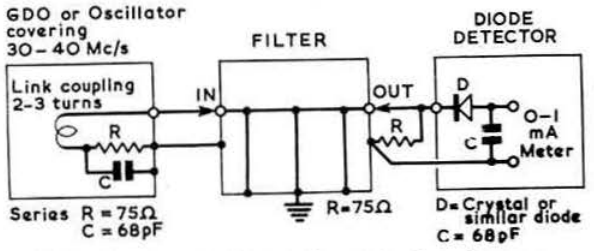

Fig. 3. Arrangement of test equipment for filter alignment.

Coil Table

In both low and high pass filters all inductors are wound with 18 s.w.g. enamelled copper wire on a ¾ in. mandrel (former).

Low Pass Filter

L1 (two required). Total length of wire including leads 13½ in. 9 turns close wound, opened to 1⅛ in. winding length (Inductance 0·4 μH).
L2 (two required). Total length of wire including leads 9¾ in. 6 turns close wound, opened to ⅝ in. winding length (Inductance 0·225 μH).
L3 (one required). Total length of wire including leads 8½ in. 5 turns close wound, opened to ⅞ in. winding length (Inductance 0·2 μH).

High Pass Filter

L4 (two required). Total length of wire including leads 14¾ in. 10 turns close wound, opened to 1⅛ in. winding length (Inductance 0·49 μH).
L5 (one required). Total length of wire including leads 9¾ in. 6 turns close wound, opened to ½ in. winding length (Inductance 0·24 μH).

Capacitor Table

Low Pass Filter

C1 (two required). Total capacitance 52pF maximum made up of a 5–35pF ceramic variable in parallel with 17pF fixed.
C2 (one required). Total capacitance 85pF maximum made up of 5–35pF ceramic variable in parallel with a 50pF fixed.

Although ceramic variable capacitors are suggested above on the grounds of economy, air spaced variables are to be preferred for use in filters for transmitters in the high power class. Other combinations of variable and fixed capacity may be used provided the total meets the specification. At least 20pF variable capacity should be allowed.

High Pass Filter

C3 (two required). Total capacitance 65pF maximum made up of a 5–35pF ceramic variable in parallel with 30pF fixed.
C4 (two required). Total capacitance 83pF comprising close tolerance capacitors of 33pF and 50pF in parallel.
C5 (one required). Total capacitance 103pF maximum made up of a 5–35pF ceramic variable in parallel with 68pF fixed.

the meter should read about 300 microamps below 32 Mc/s, but above this frequency the reading will fall rapidly. Between 36 and 38 Mc/s there may be a small peak but this can be eliminated by adjusting C2.

Repeating the test is good practice and helps to achieve optimum results as well as demonstrating in a practical way the filter characteristics.

If each C1 is tuned at 35 Mc/s instead of 32 Mc/s the filter will provide fairly high attenuation extending over the television Channel 1.

High Pass Filter In this case the test oscillator should be set at 40 Mc/s and the coupling adjusted to give about 300 microamps deflection on the meter with the filter out of circuit. Set the oscillator to 38 Mc/s and connect the filter according to Fig. 3. Now tune each C3 until the meter reading just begins to fall. Continue to do this a number of times and swing the oscillator from 30 Mc/s to 40 Mc/s in the process. The action of the filter should show that above 38 Mc/s the meter reads about 300 microamps while below 38 Mc/s its value falls rapidly. There may be a small peak at approximately 32 Mc/s but by tuning C5 it can be completely eliminated. The same remarks on repeating the test apply.

If each C3 is adjusted at 36 Mc/s instead of 38 Mc/s the filter will show fairly high attenuation extending down to 28 Mc/s, which is useful in the case of 10m operation.

More detailed notes on alignment together with the description of a test oscillator and a calibrated output meter for measuring attenuation levels will be included in a later article.

Matching the Filter to the Feeder

It is not generally appreciated that link couplings and pi-output networks must always be proved a correct match into the 75 ohm co-axial feeder if the filters are to achieve their

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COIL DATA

L1, 5 turns 18 s.w.g. tinned copper, ¼ in. diameter, ¾ in. long.
L2, 8 turns 18 s.w.g. tinned copper, ¼ in. diameter, ¾ in. long, tapped approximately 6 turns from anode end (see text).
L3, 3½ turns 18 s.w.g. tinned copper, ¾ in. diameter, ⅜ in. long.
L4, 3 turns 16 s.w.g. tinned copper, ¾ in. diameter, ⅜ in. long, centre tapped.
L5, 20 turns 30 s.w.g. enamelled on ¼ in. diameter Aladdin former with dust-iron core in screening can.
L6, 2 turns 30 s.w.g. enamelled wound over "cold" end of L5.
L7, 2 turns 30 s.w.g. enamelled wound over the "cold" end of L8.
L8, 24 turns 30 s.w.g. enamelled on ¼ in. Aladdin former with dust-iron core in screening can.
L9, 19 turns 30 s.w.g. enamelled on ¼ in. former with dust-iron core.
L10, 18 turns 30 s.w.g. enamelled on ¼ in. former with dust-iron core (last 4 turns wound on "cold" end of L9 and shown as L10A in Fig. 1).
L11, 5 turns 30 s.w.g. enamelled wound on L10 former; spaced ⅛ in. approx. from "cold" end of L10.

regeneration. Should this trouble occur, altering the h.t. tapping point on L2 may be effective but should only be resorted to if all else fails. The layout of the r.f. stage components (Fig. 4) should be examined first if regeneration is evident. The grid lead to V1a should be as short as possible. Bending the valve base tag down towards the chassis will help considerably in this respect especially if a solder tag is arranged to come into direct contact with the valveholder tag. Grounded grid amplifiers have a tendency towards instability if there is a serious mismatch in their input circuits. The test for such instability is to substitute an 80 ohm resistor for the co-axial line to the signal source. If the instability ceases, correctly matching the aerial to the feeder should overcome the trouble when the signal source is again connected. Another method is to lengthen the co-axial cable. Tightening the coupling between L2 and L3 is also helpful.

The tapping point on L2 may be checked with the point of a pencil: there should be little or no change in mixer grid current when the tapping point is touched with a pencil. The point of connection should be altered until this condition is obtained. It must be remembered that any of these alterations will necessitate retuning C3.

In order to check the oscillator and tune it to the correct frequency it will be necessary to disconnect the signal input and reconnect R3. If the oscillator is functioning there should be an increase in mixer grid current when h.t. is applied.

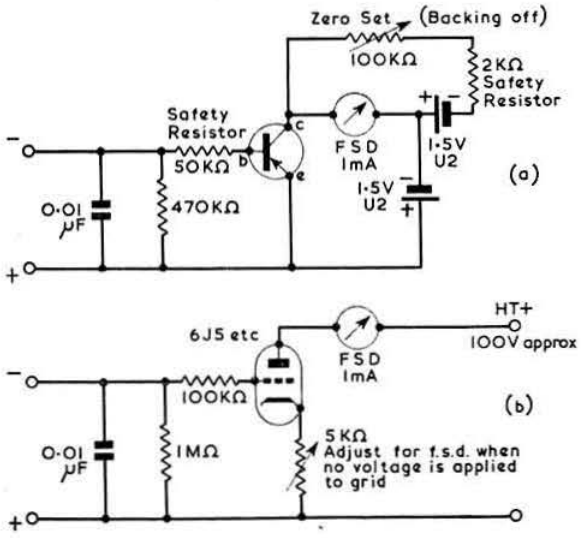

Fig. 6 (a). Transistor d.c. amplifier for measuring mixer grid current (adjust for **maximum** *reading). (b) Valve voltmeter for measuring mixer grid current (adjust for* **minimum** *reading).*

An absorption wavemeter (or g.d.o. with no h.t. applied) should be set to 120 Mc/s and C7 (the main tuning control) set to mid-scale. C6 should then be adjusted until a dip is noted in the mixer grid current when the absorption wavemeter is held about an inch away from L4. Next reconnect R4 and the co-axial link between the converter and the i.f./a.f. section, plug a suitable aerial into CS1 and tune C7 for a strong local signal. The slug in L6 can then be peaked with an insulated screwdriver. Final adjustments are best carried out on weak signals.

All the controls tend to be interdependent and a certain amount of patience is needed to get the best performance out of this receiver.

Three of these receivers have been built using different intermediate frequencies and there is little to choose between them as regards performance, although more oscillator pulling is experienced with the lower i.f. model. The 25 Mc/s version could suffer from second channel interference from stations in the 80/90 Mc/s v.h.f. broadcast band but in practice all three are capable of excellent results.

Acknowledgments

The writer is indebted to G3GOZ for testing the receiver at his station and to G2UJ, G3FD, G3LCK and G6LL who also carried out tests on the receiver.

Low and High Pass Filters for All (Continued from p. 400)

design performance; in fact no filter will work correctly unless its input and output impedances are properly matched to suit the overall feeder impedance.

Using a short length of 75 ohm cable, one end connected to the transmitter and the other terminated in a non-inductive 75 ohm resistor with a r.f. thermal ammeter in one side, the link or pi-output network should be adjusted to produce maximum reading on the ammeter. Inserting the filter in the co-axial feeder between the transmitter and the load should produce no change in the meter reading; transmitter loading and input being kept at a constant value. More details on this aspect will also be given in a later article.

General Considerations

A good earth should be used with all radio equipment, both amateur and domestic. Mains earths are inherently unreliable and should be avoided. Failing a ground earth, the *iron* pipe of a cold water main supply is usually satisfactory. The filter case and co-axial braid should be securely bonded to earth otherwise they may be at r.f. potential and the filter action non-existent.

Extreme caution should be exercised with a.c./d.c. equipment where one side of the chassis is at mains potential. Most modern TV receivers fall into this category. It is essential to check that the neutral is always connected to the chassis. In such cases the earth lead should be connected to the chassis through a 0·01 μF capacitor of at least 1,000 volt d.c. test. It is important to make quite sure that the coax socket is in no way directly connected to the receiver chassis otherwise the joining of an earth to the filter box may well have disastrous consequences.

Twin 80 ohm cable will not satisfy the stringent requirements for matching and screening demanded in all applications of the filters. Where it is in use the short though somewhat unethical remedy is to deliberately introduce a quarter-wavelength of 75 ohm co-axial cable (measured to suit the TV channel concerned), making sure that the braiding is attached to the earthy side of the twin feeder socket at the receiver. If no earth is present a 0·01 μF capacitor should be introduced as for a.c./d.c. receivers.